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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

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Applicant's or agent's file reference Q080PCT	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/EP2004/007098	International filing date *(day/month/year)* 30.06.2004	Priority date *(day/month/year)* 01.07.2003
International Patent Classification (IPC) or national classification and IPC G06T3/00		
Applicant THOMSON LICENSING SA		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 10 sheets, as follows:
      - ☐ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☐ Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
18.02.2005	08.07.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Deltorn, J-M Telephone No. +31 70 340-3468

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/EP2004/007098

10/562666

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-3, 5-24, 26-28	as originally filed
4, 4a, 25	received on 22.02.2005 with letter of 14.02.2005

Claims, Numbers

1-14	received on 22.02.2005 with letter of 14.02.2005

Drawings, Sheets

1/1	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-14
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-14
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following document:

D1 : COLLINS R T ET AL: "Matching perspective views of coplanar structures using projective unwarping and similarity matching" COMPUTER VISION AND PATTERN RECOGNITION, 1993. PROCEEDINGS CVPR '93, 1993 IEEE COMPUTER SOCIETY CONFERENCE ON NEW YORK, NY, USA 15-17 JUNE 1993, LOS ALAMITOS, CA, USA, IEEE COMPUT. SOC, 15 June 1993, pages 240-245

2. **CLAIM 1**

2.1 Novelty

The document D1 is regarded as being the closest prior art to the subject-matter of claim 1 and shows (the references in parentheses applying to this document):

An automatic resetting method using electronic means intended for a geometric model of a scene over a picture of a scene (page 240, section 1), characterized in that the electronic device calculates a fine homography function Hr for resetting into two main phases:

(i) a first preliminary phase of determination of an average resetting homography consisting in determining an average homography function Hm applicable to the model with average adjustment over a sample of pictures of the scene taken previously (page 242, first paragraph of section 3),

(ii) a second, rough resetting phase consisting after application of the average homography function Hm to the model in determining a rough homography function Hg (page 242, first paragraph of section 3).

The subject-matter of claim 1 differs from this known method in that:

(a) The model and the picture of the scene being stored in the memory of an electronic device in the form of pixel matrices, the scene including fixed references with respect to the remainder of the scene, whereas the references may be specifically detected within the matrices,

(b) The picture being taken by a camera arranged in a given zone with respect to the ground in a location of the zone and according to a shot angle determined relative to the scene, the electronic means comparing the picture with the model having been adjusted in perspective by homography for superimposition of the references,

(c) The second, rough resetting phase further includes the steps of:
   (i) extracting reference pixels and producing a pair of binary matrices containing vectical and an horizontal contour points,
   (ii) for each horizontal and vertical reference matrices, computing a distance matrix in which the value of each element of the matrix corresponds to the distance to the closest reference point, according to the horizontal line and the vertical line respectively
   (iii) applying an average homographic function to the reference lines of the model and comparing the resulting matrix to the horizontal and vertical reference matrices; calculating a homography function by regression with m inimisation of the medial of the square of the distance between pairs of matched pixels,
   (iv) identifying the pairs of pixels corresponding to non aberrant matches
   (v) adjusting by least square regression over all the non aberrant pixel pairs the homography function in order to produce a rough homography.

(d) The feature of Claim 1 includes an additional third step of refinement of the Homography function.

The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

2.2 Inventive Step:

The problem to be solved by the present invention may be regarded as:

How to provide an automatic resetting method between an image of a scene including fixed references and a geometric model of said scene

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons:

The incremental calculation of a fine homography function between a scene and a geometric model of said scene disclosed in Claim 1 provides an improved, more robust, resetting method that allows, in particular, to match a model on an image corresponding to said model seen in perspective without requirering to determine a vanishing point out of reference lines detected in the image. The method of Claim 1 is indeed based on the matching of reference points and is therefore less prone to being affected by the partial occlusion of reference lines by foreground objects in the image. Such a method is not known from nor suggested by the available prior art.

3. INDEPENDENT CLAIMS 11, 13 AND 14

The same reasoning applies, mutatis mutandis, to the corresponding independent device claim 11 and information storage medium including a programme claims 13 and 14, which are therefore also considered novel and inventive (Articles 33(2) and 33(3) PCT).

4. DEPENDENT CLAIMS 2-10 AND 12

Claims 2-10 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Claim 12 dependent on claim 12 and as such also meets the requirements of the PCT with respect to novelty and inventive step.

Deriche filtering is used. The intersections of the different straight lines found form a collection of particular points serving for resetting with respect to the theoretic model. The initial resetting is performed manually on the first picture while associating 4 points identified in the picture with their counterpart in the theoretic model. For the following pictures, an algorithm for compensation of the dominant movement enables to track the matching points throughout the sequence. The shortcomings of such method are mainly the use of manual initialisation, the sensitivity of the line detection algorithm and the difficulty of adaptation to a more complex ground model which does not exhibit any equivalent ground markings.

One also knows following documents:

COLLINS R T and AL: "Matching perspective views of coplanar structures using projective unwarping and similarity matching" COMPUTER VISION AND PATTERN RECOGNITION, 1993, PROCEEDINGS CVPR '93, 1993 IEEE COMPUTER SOCIETY CONFERENCE ON NEW YORK, NY, USA 15-17 JUNE 1993, LOS ALAMITOS, CA, USA, IEEE COMPUT. SOC. June 15,1993, pages 240-245;

CHETVERIKOV D., KHENOKH Y.: "Matching for shape defect detection" LECTURE NOTES IN COMPUTER SCIENCES, vol. 1689, 1999, pages 367-374, HEIDELBERG;

FAUGERAS, O.: "Three dimensional computer vision – a geometric viewpoint" 1993, MIT PRESS;

US 2002/167512 A1 (BRODSKY TOMAS ET AL) November 14, 2002.

The present invention suggests an alternate method which does not resort to manual initialisation of the resetting algorithm for each video sequence processed. It is moreover robust to the problem associated with contour detection, which is not the case of the methods described previously. Within the framework of the invention, the terms ground and scene are considered as equivalent.

Thus, the invention concerns, an automatic resetting method using electronic means intended for a geometric model of a scene over a picture of the scene, the model and the picture of the scene being stored in the memory of an electronic device in the form of pixel matrices, the scene including fixed references with respect to the remainder of the scene, whereas the references may be specifically detected within the matrices, the picture being taken by a camera arranged in a given zone with respect to the ground in a location of the zone and according to a shot angle determined relative to the scene, the electronic means comparing the picture with the model having been adjusted in perspective by homography for superimposition of the references.

The rough homography H_g is finally obtained by least square regression calculation carried out over all the pairs judged as non- aberrant. It should be noted that the calculation of H_g may be fine-tuned further by iterating the process described previously, new matching pairs of points being obtained by applying the homography H_g to the model. One may explain the calculation of the rough homography in the form of an algorithm with:

- p1 : corresponding in the picture to a point p of the theoretic ground resetted by *Hm* (average homography)
- p2 : contour point closest to p1

1. For each point p belonging to the theoretic contour:
   a. p1=Hm(p)
   b. if p is a point belonging to a vertical line p2=p1+Dv(p1)
   c. if not p2= p1+Dh(p1)
2. Robust calculation of the homography on the basis of the collection of the couples (p1,p2) found
   a. Perform n random draws of 4 couples of points
   b. For each draw:
      i. Calculate linearly the homography on the basis of the 4 couples
      ii. Calculate the medial error
   a. For the homography having given the minimal medial error
      i. Keep the non-aberrant couples (those whereof the absolute value of the residue is smaller than K times $\hat{\sigma}$).
      ii. Recalculate the rough homography Hg on the basis of all these couples

c) the fine resetting

The previous phase has therefore enabled to generate a matrix of rough homography H_g which is close to the final solution. The present step consists in fine-tuning the parameters of this homography in order to produce a fine

CLAIMS

1. An automatic resetting method using electronic means intended for a geometric model of a scene over a picture of the scene, the model and the picture of the scene being stored in the memory of an electronic device in the form of pixel matrices, the scene including fixed references with respect to the remainder of the scene, whereas the references may be specifically detected within the matrices, the picture being taken by a camera arranged in a given zone with respect to the ground in a location of the zone and according to a shot angle determined relative to the scene, the electronic means comparing the picture with the model having been adjusted in perspective by homography for superimposition of the references,
characterised in that the electronic device calculates a fine homography function H_f for resetting into three main phases:
- - a first preliminary phase of determination of an average resetting homography consisting in determining an average homography function H_m applicable to the model with average adjustment over a sample of pictures of the scene taken previously,
- - a second, rough resetting phase consisting after application of the average homography function H_m to the model in determining a rough homography function H_g, said second rough resetting phase having following steps:
  - in a first step, an extraction process is applied to the picture enabling, according to detection criteria, to detect in the picture matrix of the pixels which may represent references of the scene and to form a first picture reference binary matrix M_{rh} including horizontal contour points and a second picture reference binary matrix M_{rv} including vertical contour points,
  - in a second step, for each horizontal reference binary matrix M_{rh}, respectively vertical reference binary matrix

M_{rv}, a horizontal reference distance matrix, M_{dh}, respectively a vertical reference distance matrix M_{dv} including for each element of the matrix the distance value with respect to the closest reference according to the vertical line, respectively the horizontal line is calculated,

- in a third step, all the reference lines of the model are applied the average homographic function H_m in order to produce a binary average adjusted matrix M_{am} which is compared with the vertical M_{dv}, respectively horizontal M_{dh} reference distance matrices, for pixel matching purposes, a homography function H_{opt} is then calculated by regression with minimisation of the medial of the square of the distance between pairs of matched pixels,

- in a fourth step, the pairs of pixels corresponding to non-aberrant matches are identified,

- in a fifth step, H_{opt} is adjusted by least square regression calculation over all the non-aberrant pixel pairs in order to produce the rough homography H_g,

- - a third, fine resetting phase consisting after application of the rough homography function H_g to the model in determining a fine homography function H_f.

2. A method according to claim 1, characterised in that in the preliminary step of determination of an average resetting homography, at least one sample picture is selected among a collection of pictures taken of the given location, the references on the sample picture(s) are detected and an average homographic function H_m is calculated enabling superimposition between the model subjected to the average homographic function and the sample picture(s), superimposition being reached for least error square minimization of the distance between reference points of sample picture(s) and the model subjected to the average homographic function.

3. A method according to claim 1 or 2, characterised in that in the second, rough resetting phase for the second step: in the horizontal reference distance matrix M_{dh} each element of said matrix specify the distance d in number of pixels relative to the reference line along a vertical axis, the distance values on the reference line and those of a column without any reference line pixel being nil, the distance values along the vertical line increasing in absolute value as the element moves away relative to the reference line, the distance values of the elements being of opposite signs on both sides of the reference line,

in the vertical reference distance matrix M_{dv} each element of said matrix specifying the distance d in number of pixels relative to the reference line along a horizontal axis, the distance values on the reference line and those of a line without reference line pixel being nil, the distance values along the horizontal line increasing in absolute value as the element moves away relative to the reference line, of the elements being of opposite signs on both sides of the reference line,

and that for pixels matching:

with, for each pixel p(i,j) of the average adjusted matrix derived from a resetted pixel of the model belonging to a vertical reference line and positioned at the line i and at the column j of the average adjusted matrix M_{am}, the allocation of a corresponding pixel obtained by adding the value d in i and j of the vertical reference matrix M_{dv} to the value j, and matching the pixels ((i,j), (i,j+d)),

with, for each pixel p(i,j) of the average adjusted matrix derived from a resetted pixel of the model belonging to a horizontal reference line and positioned at the line i and at the column j of the average adjusted matrix M_{am}, the allocation of a corresponding pixel obtained by adding the value d in i and j of the horizontal reference matrix M_{dv} to the value j, and matching the pixels ((i,j), (i+d,j)),

and that thee homography function H_{opt} calculated by regression with minimisation of the medial of the square of the distance between pairs of matched pixels, is carried out over n collections of four pairs of matched pixels.

4. A method according to the claim 1, 2 or 3, characterised in that, in the fourth step of the second, rough resetting step, a pair of pixels corresponds to a non-aberrant match, if, for the pixel of the average adjusted matrix M_{am} of the match in question, the distance between the pixel matched by using the reference matrices M_{dh}, M_{dv}, and that obtained by the homography H_{opt} is smaller than or equal to a preset threshold.

5. A method according to claim 3 or 4, characterised in that the reference detection criteria are chosen individually or in combination among:

- a specific colour of the reference with respect to the remainder of the scene,
- a specific tone of the reference with respect to the remainder of the scene,
- a specific grey level of the reference with respect to the remainder of the scene,
- a specific shape of the reference, notably a line, an angle between two lines crossing each other, a parallelism between two lines,
- a specific orientation of the reference,
- a line closest and parallel to an edge of the picture matrix.

6. A method according to any of the the claims previous characterised in that the extraction process comprises a preliminary Cany-Deriche filtering step of the picture in order to obtain a gradient picture and that the process continues with the gradient picture.

7. A method according to any of the previous claims, characterised in that in the third, fine resetting phase, the rough homography H_g is applied to the model and the result is compared to both horizontal and vertical distance matrices

with adjustment of the homography by a so-called Powel alternate single-dimension iterative minimisation method.

8. A method according to any of the previous claims, characterised in that the pictures evolve with time according to sequences corresponding to different shot locations and/or angles and in that the electronic device comprises means enabling moreover to determine during the first, average resetting preliminary phase, as many average homography functions H_m as there are different shot locations and angles.

9. A method according to any of the previous claims, characterised in that the phases and steps are implemented in the electronic means which are programmable logic units with a programme and that the programmable logic comprises a microprocessor or a digital signal processor (DSP) and, preferably, of the general-purpose or dedicated microcomputer type.

10. A method according to any of the previous claims, characterised in that the scene is a sports ground including references in the form of delineating lines, notably a European or American "football" pitch or a tennis ground.

11. Automatic resetting device using electronic means intended for a geometric model of a scene over a picture of the scene, the model and the picture of the scene being stored in the memory of an electronic device in the form of pixel matrices, the scene including fixed references with respect to the remainder of the scene, whereas the references may be specifically detected within the matrices, the picture being taken by a camera arranged in a given zone with respect to the ground in a location of the zone and according to a shot angle determined relative to the scene, the electronic means comparing the picture with the model having been adjusted in perspective by homography for superimposition of the references,

characterised in that it comprises means enabling to calculate a fine homography function H_f for resetting into three main phases:

- - a first preliminary phase of determination of an average resetting homography consisting in determining an average homography function H_m applicable to the model with average adjustment over a sample of pictures of the scene taken previously,

- - a second, rough resetting phase consisting after application of the average homography function H_m to the model in determining a rough homography function H_g, said second rough resetting phase having following steps:

  - in a first step, an extraction process is applied to the picture enabling, according to detection criteria, to detect in the picture matrix of the pixels which may represent references of the scene and to form a first picture reference binary matrix M_{rh} including horizontal contour points and a second picture reference binary matrix M_{rv} including vertical contour points,

  - in a second step, for each horizontal reference binary matrix M_{rh}, respectively vertical reference binary matrix M_{rv}, a horizontal reference distance matrix, M_{dh}, respectively a vertical reference distance matrix M_{dv} including for each element of the matrix the distance value with respect to the closest reference according to the vertical line, respectively the horizontal line, is calculated,

  - in a third step, all the reference lines of the model are applied the average homographic function H_m in order to produce a binary average adjusted matrix M_{am} which is compared with the vertical M_{dv}, respectively horizontal M_{dh} reference distance matrices, for pixel matching purposes, a homography function H_{opt} is then calculated by regression with minimisation of the medial of the square of the distance between pairs of matched pixels,

- in a fourth step, the pairs of pixels corresponding to non-aberrant matches are identified,

- in a fifth step, H_{opt} is adjusted by least square regression calculation over all the non-aberrant pixel pairs in order to produce the rough homography H_g,

- - a third, fine resetting phase consisting after application of the rough homography function H_g to the model in determining a fine homography function H_f.

12. A device according to claim 11, characterised in that the electronic means are of the general-purpose or dedicated microcomputer type.

13. An information storage medium including a programme intended for operating the device of claim 11.

14. An information storage medium including a programme intended for operating the device of claim 11 and at least according to the method of claim 1 among the method-related claims 1 to 10.